NOISE AND VIBRATION

The proposed Maglev train system has four sources of potential noise and vibration: (1) noise and vibration caused by the construction of the Maglev system and facilities; (2) noise and vibration caused by the operation of the Maglev train; (3) noise produced by system support facilities and equipment; and (4) the increase in street traffic noise which would result from cars and buses accessing the passenger stations for arrivals and departures.

The most common unit for measurement of noise level is the decibel (dBA). Figure 1 illustrates the noise level for common indoor and outdoor noise sources and relates the noise level to human perception; e.g., quiet, loud, painful.

Construction Noise and Vibration

Construction noise varies greatly depending on the construction process, type and condition of equipment used, and layout of the construction site. Many of these factors are left to the contractor's discretion, which makes it difficult to accurately estimate levels of construction noise. Prior to construction, it must be assumed that the noisiest option will be chosen. Mitigation measures, such as hours of operation adjacent to residential areas, can then be outlined and included in the construction contract bid documents.

Overall, construction noise levels are governed primarily by the noisiest pieces of equipment. Jackhammers, impact pile drivers, and vibratory pile drivers would be most likely to exceed noise criteria. Table 1 shows the minimum distances at which these equipment types could encroach on sensitive land uses without exceeding the noise criteria. When these construction equipment types come within the distances listed in Table 1, there could possibly be a noise impact for the indicated land use category.

Table 1. Construction Equipment Noise Impact Distances

Equipment	Distance in meters (feet) to Residential Land Use*	Distance in meters (feet) to Commercial or Industrial Land Use
Jackhammer	17 (56)	5 (18)
Pile Driver, Impact	54 (177)	17 (56)
Pile Driver, Vibratory	30 (100)	10 (32)

Note: * - This land use includes any property with sleeping quarters (e.g., residences, hotels, RV parks).

It is also anticipated that there could be vibration impacts during some of the construction stage of the project. The project will require heavy ground-prep and earthmoving equipment such as bulldozers and pile drivers to construct the guideway and other project facilities. Pile drivers are one of the highest producers of noise and vibration among construction equipment, and may be used to lay the footing of the support columns for the guideway.

Figure 1. Noise Levels from Common Indoor and Outdoor Noise Sources

How Loud It Sounds	Noise Level dBA		Common Indoor Noise Levels	Common Outdoor Noise Levels
		140	Long range gun at 0 feet	
Painful				
		130		
			Hard Rock Band	Miltary Jet Aircraft Afterburner at 100 feet
		120		
Extremely Loud		110	Night Club Dance Floor	Chain Saw at 2 feet
		100	Inside Subway Station with Train Passing	Gas Lawnmower at 3 feet
Very Loud		90	Food Blender at 3 feet	
			Garbage Disposal at 3 feet	Diesel Truck at 50 feet
		80	Shouting at 3 feet	Downtown Major City Daytime
		70	Vacuum Cleaner at 10 feet	Gas Lawnmower at 100 feet
Loud				Commercial/Retail Area Heavy Traffic at 300 ft.
		60	Normal Conversation at 3 feet	Urban Area Daytime
			Large Business Office	
		50	Dishwasher next Room	
Moderate				Urban Area Nighttime
		40	Large Conference Room	
		30	Bedroom at Night	
Quiet			Broadcast and Recording Studio (Vacant)	Quiet Rural Area Nighttime
		20		
				Remote Wilderness Area
		10	Human Breathing at 3 feet	
Very Quiet				
		0		
0 dBA Ref. Level is Threshold of Hearing In Young Humans		-10		

Two types of construction vibration impact are: (1) community annoyance; and (2) building damage. Community annoyance occurs when construction vibration rises significantly above the threshold of human perception for extended periods of time. Building damage can be cosmetic or structural. When construction equipment items approach sensitive receptor locations, within the approximate distances listed in Table 2, there would be a potential impact and mitigation may be required.

Table 2. Construction Equipment Vibration Impact Distances

<table>
<tr><th>Equipment</th><th colspan="2">Distance to Vibration Annoyance
in meters (feet)</th><th>Distance to Vibration Building Damage
in meters (feet)</th></tr>
<tr><td>Pile Driver, Impact</td><td>160 (525)(1)</td><td>85 (280)(2)</td><td>15 (50)</td></tr>
<tr><td>Pile Driver, Vibratory</td><td>100 (330)(1)</td><td>55 (180)(2)</td><td>10 (35)</td></tr>
<tr><td>Large bulldozer</td><td colspan="2">25 (85)</td><td>--</td></tr>
<tr><td>Caisson drilling</td><td colspan="2">25 (85)</td><td>--</td></tr>
<tr><td>Loaded trucks</td><td colspan="2">25 (85)</td><td>--</td></tr>
<tr><td>Wheel impactor</td><td colspan="2">60 (200)</td><td>15 (50)</td></tr>
<tr><td>Vibratory roller</td><td colspan="2">80 (265)</td><td>15 (50)</td></tr>
</table>

1. Frequent Events -- more than 70 vibration events per day.
2. Infrequent Events -- fewer than 70 vibration events per day.

-- Distance is less than 3 meters (10 feet).

Operational Noise and Vibration

The noise from non-contact Maglev propulsion systems is primarily due to the aerodynamics of the high-speed train. When operating at less than maximum speeds, different aspects of the train noise become predominant. Table 3 shows three speed categories and lists the dominating noise sources of the Maglev train.

Table 3. Noise Categories for Maglev System

Category	Speed Range, mph	Dominant Noise Sources
I	0 – 50	Propulsion or auxiliary equipment noise
II	50 – 160	Mechanical noise and/or structural noise from guideway vibrations
III	160 – 300	Aerodynamic noise resulting from the fast-moving airflow over the surface of the train

Source: FRA, 1998

One particular noise effect of interest, caused by the abruptness of an approaching train, is the time it takes for the noise level to go from the normal background to the maximum produced by the Maglev train which is only about two seconds. During this short period of time, the noise level increases approximately 35 to 40 dB, which creates an impact called “startle effect.”

Startle Effects

Increased annoyance is likely to occur for train noise events with rapid onset rates, caused by the abruptness of an approaching train. This is also called the startle effect. The relationship of speed and distance are used to determine areas where startle effects may occur. Impacts from startle effects assume open, flat terrain with unobstructed view of the tracks in both directions. Startle effects occur when humans are within the distances shown in Table 4. The potential for startle for the most part is confined to an area very close to the tracks. Any person within the distances shown in Table 4 would experience startle effects whether, indoors, outdoors, or in a vehicle on an adjacent roadway.

Table 4. Extent of Areas Potentially Impacted by Startle Effects

Train Speed, km/h (mph)	Maximum Distance of Startle Effects, meters (feet)
161 (100)	6 (21)
201 (125)	8 (26)
241 (150)	10 (32)
282 (175)	11 (37)
322 (200)	13 (42)
362 (225)	14 (47)
402 (250)	16 (53)
443 (275)	18 (58)
483 (300)	19 (63)
500 (311)	20 (65)

Source: FRA, 1998

Train Passby Noise

The noise level during a Maglev train passby is highly dependent upon the Maglev speed. Table 5 shows the noise levels generated by the Maglev train operation at noise sensitive sites along Interstate-15 between Las Vegas and Primm, Nevada. These results show that for Category I speeds (0 – 50 mph), no noise impacts would be expected. At Category II speeds (50 – 160 mph), noise sensitive sites near the guideway could experience noise exposure “Impact” or “Severe Impact” based on FRA guidelines. Category III speeds (160 – 300 mph) also have the potential for “Impact” or “Severe Impact” to noise sensitive sites, but these speeds are achieved only in rural areas.

Table 5. Noise Levels Generated by Maglev Operation at Noise Sensitive Sites

Site No.	Side of I-15	Distance to the edge of guideway, m (ft)	Maglev speed(1), km/h (mph)	Day-Night Average Sound Level for Maglev Operations(2), DBA	Background Day-Night Average Sound Level(2), dBA	Criteria for this Land Use, Impact/Severe Impact, dBA(3)	Impact / Severe Impact(4)
1	East	155 (507)	50 (31)	39	55	55/61	No/No
2	East	64 (209)	100 (62)	45	60	58/63	No/No
3	East	74 (244)	445 (276)	67	60	58/63	Yes/Yes
4	West	82 (270)	250 (155)	54	70	64/69	No/No
5	East	61 (200)	250 (155)	56	60	58/63	No/No
6	East	27 (90)	250 (155)	61	65	61/66	No/No
7	East	26 (85)	250 (155)	61	65	61/66	No/No
8	East	35 (115)	250 (155)	59	65	61/66	No/No
9	East	37 (120)	250 (155)	59	65	61/66	No/No
10	East	38 (125)	250 (155)	59	65	61/66	No/No
11	East	99 (325)	250 (155)	53	60	58/63	No/No
12	East	17 (55)	250 (155)	64	70	64/69	No/No
13	East	82 (270)	120 (74)	45	50	53/60	No/No
14	West	30 (100)	250 (155)	60	65	61/66	No/No
15	West	44 (145)	250 (155)	58	60	58/63	No/No
16(5)	East	43 (140)	250 (155)	54(5)	65(5)	66/71(5)	No/No
17(6)	*	20 (65)	250 (155)	59(5)	65(5)	66/71(5)	No/No
17(7)	*	108 (355)	250 (155)	48(5)	65(5)	66/71(5)	No/No
18(6)	*	46 (150)	250 (155)	58	60	58/63	No/No
19(6)	*	34 (110)	250 (155)	60	60	58/63	Yes/No
19(7)	*	139 (455)	250 (155)	50	60	58/63	No/No
20(6)	*	17 (55)	250 (155)	64	60	58/63	Yes/Yes
20(7)	*	125 (410)	250 (155)	51	60	58/63	No/No
21	*	37 (120)	200 (124)	54	60	58/63	No/No
22	*	41 (135)	50 (31)	47	50	53/60	No/No

Notes:
1 - Speeds were provided by Transrapid International.
2 - Project noise levels for the Maglev operations and existing background noise levels are in terms of day-night average sound level, Ldn, unless noted.
3 - The noise criteria shows two levels of noise exposure, "Impact" and "Severe Impact" based on FRA guidelines. The criteria are in terms of the day-night average sound level, Ldn, unless noted.
4 - If the Maglev operation noise exceeds one or both of the levels in the criteria column, an "Impact" or "Severe Impact" is indicated accordingly.
5 - Site No. 16 and 17 are category 3 land use. The Maglev operation noise, background noise and criteria for these sites are peak hour daytime Leq, rather than Ldn.
6 - Industrial alignment.
7 - UPRR alignment
* - The guideway alignment in this area departs from the I-15 corridor and follows city streets or railroad corridors.

Train Passby Vibration
Because of the nature of the Maglev system, the vibration produced during a train passby is very low compared to conventional high-speed trains. This is because of the fact that the Maglev has no contact with the guideway structure and the vibrations are not mechanically transmitted by contact. According to German studies for the TR07 Maglev train (Transrapid, 1999), the ground vibration produced by a Maglev train passing at 250 km/h (155 mph) is below the threshold of human perception at distances greater than 32 meters (105 feet) from the guideway. At 420 km/h (260 mph), the vibration is below the threshold of human perception at distances greater than 64 meters (210 feet) from the guideway. At greater distances than these, the vibration would not be perceivable, and at closer proximity, the vibration would be perceivable.

Support Facilities and Equipment Noise

Passenger Station
Depending on their location, Maglev passenger stations will either be integrated into existing facilities or be constructed as new facilities. Extensive transportation access such as public transit, shuttles, taxis, rental cars, and park and ride facilities may be constructed as part of the station. Thus, traffic noise impact from the passenger station is likely to occur. Traffic noise impacts would be anticipated if the future traffic noise levels approach or exceed FHWA and local noise abatement criteria. The heating and air conditioning units for the passenger stations and parking lot noises such as car horns or door slamming could also cause noise impacts.

Electrical Substation
Substations are typically installed along the route at intervals of up to 50 km dependent on the train interval, speed profile, and load factors. The dimension of a major substation would be approximately 80 meters (262 feet) by 100 meters (328 feet). In addition to the transformers and power conditioning/conversion components, substations contain equipment for energy supply, cooling, and control system. Noise impact from the electric substation is likely to be significant due to outdoor transformers and cooling system for the switchgear building.

Table 5 lists noise levels for various equipment items in a typical electrical substation:

Table 5: Equipment Noise Levels

Equipment	Noise level at 1 m (3 ft), dBA
Braking Resistor	67
Input Transformer	65
Output Transformer	65
Cooling System	72
Second Stage Transformer	61
Switch Choke	61

Source: Transrapid International

The cumulative noise level at the property line would depend on the individual substation layout and distance of different equipment items from the property line. There would be noise impacts if noise levels at the property line exceed the noise limits specified by local jurisdictions.

Decentral Maintenance Facility

Decentral maintenance facilities handle all the daily maintenance work for the trains and are generally located at both ends of the route. The following decentral facility components may have a noise impact to the surrounding communities:

- Maintenance hall with one track
- Guideway switches to access maintenance hall
- Train washing equipment (Indoor)
- Interior vacuuming equipment (Outdoor)
- Operation noise from day and night time employee car traffic.

Central Maintenance Facility

The central maintenance facility (approximately 400 m x 100 m) handles the longterm major periodic maintenance for the trains and is typically located near the mid-point of a route to provide convenient access from all stations. All major maintenance activities would be located inside an enclosed area. The following central facility components may have noise impacts on the surrounding communities:

- Maintenance hall with multiple Maglev train tracks
- Guideway transfer table to access the maintenance hall tracks
- Train washing and painting equipment.

Central Operation Facility

The central operation facility would be located in a commercial area. Its noise generation characteristic would be comparable to a typical business building. The only major noise source would be the heating and cooling system equipment.

Guideway Maintenance Facility

The guideway maintenance facilities are typically situated near the electric substations. They provide parking areas for guideway maintenance equipment and space for guideway maintenance workshops. Machinery and equipment used in this facility may have noise impacts at the surrounding areas. The other noise source is the diesel operated, rubber wheeled carriages, which will travel on the guideway during the nighttime for maintenance. Noise level from this train is likely to be the same as a truck and it is not anticipated to have any noise impacts.

Electrical Transformers

Electrical transformers are typically located under the guideway. Normally, they would not be considered major noise sources.